Influence of different light curing units on the bond strength of indirect resin composite restorations

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Abstract: The aim of this study was to evaluate the influence of different light sources on the bond strength of indirect resin composite restorations cemented with a dual-cure resin cement. The superficial dentin of human third molars was exposed and acid-etched and an adhesive system was applied (Single Bond 2). Four-mm-thick indirect resin composite restorations (Gradia) were fabricated and cemented using a dual-cure resin cement (Rely X). Four light sources were used to polymerize the cement: QTH – Optilux 401; LED1 – L.E.Demetron 1; LED2 – Optilight CL; and LED3 – Ultralume 5. The teeth were stored for 24 h and then sectioned, yielding stick-shaped specimens for each group with a bonded area of 1.0 mm². The specimens were then tested in a universal testing machine, at a crosshead speed of 1 mm/min. Data were analyzed using ANOVA. Bond strength mean values were: QTH: 22.5 (± 8.4); LED1: 22.7 (± 9.4); LED2: 21.4 (± 10.2); and LED3: 27.3 (± 13.8). No statistically significant difference was observed among the experimental groups. The bond strength values when the cement was polymerized using different LED lights were equivalent to the values when the QTH light was used. It can be concluded that the variety of light sources used in the present study did not influence the bond strength of indirect resin composite restorations cemented with a dual-cure resin cement.

Descriptors: Resin cements; Composite resins/standards.

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Introduction

Advances in the field of light-curing have been remarkable, mainly after the development of blue light-emitting diodes (LED) lights for the photoactivation of resin composites.[1] These new light curing devices are very compact, promise unlimited life, work at reduced voltage, do not require filters to limit the wavelength range and the light emitted is very specific for the camphorquinone/amine system.[2] These devices are composed of solid-state LEDs that use junctions of doped semiconductors based on gallium nitride to directly emit light in the blue region of the spectrum, without excessive heating.[3] These devices have improved and are now classified into generations.[1]

The first generation of LED lights was very limited[4] due to a low power density (around 150 mW/cm²), and had a worse performance than that of conventional quartz-tungsten-halogen (QTH) lights.[1] The second-generation LED lights provided superior results, delivering a greater power output.[5] These light sources have a large area chip, which allows higher power operation; thus they are capable of achieving a polymerization degree similar to that produced by QTH lights with the same exposure time.[2] An increase in temperature may occur; however it is dissipated quite quickly. The large area chip and a special thermal management, which prevents overheating, allow high power operation without thermal damage of the curing unit. These factors allow a higher light output and shorter exposure times.[1,2,5] The spectral distribution of both first- and second-generation LED lights is narrower than that provided by QTH lights.[6] However, these units are only able to effectively polymerize camphorquinone-amine-based composites. Also, LED light sources are less effective in light curing darker composite shades as these materials do not achieve a high degree of conversion when photoactivated with this type of units.[4] An increase in the power density and spectral distribution delivered would overcome the aforementioned drawbacks.[4]

A third generation of LED lights was then developed.[1,6] In this case, there is an association with one or more low power density chips that emit light wavelengths in the violet color area of the electromagnetic spectrum (400 nm).[1] The once narrow bandwidth and photo-initiator-specific nature of first- and second-generation lights was eliminated. The inclusion of short wave violet light may allow curing of alternate photoinitiators found in some specific types of resin-based restorative materials. Thus, LED lights can now be classified as "broad-banded" with respect to their output range. As the heating of these devices is directly correlated with their power density and the spectral distribution delivered, the LED elements must be cooled, or otherwise these components may burn out.[1]

The use of LED lights to polymerize direct composite restorations has been widely assessed in the dental literature.[5,7] Therefore, the influence of LED devices on the microtensile bond strength of indirect composite restorations has, up to now, not been evaluated. The purpose of the present study is to investigate the influence of a variety of generations of blue light-emitting-diode lights to polymerize a dual-cure resin cement when an indirect resin composite is used to restore dental specimens. The null hypothesis to be tested is that there will be no difference in the bond strength values when laboratory processed resin restorations are cemented using a dual-cure resin cement. A selection of commercial LED lights was used to polymerize this restorative material and the results were compared to those of a conventional QTH light.

Material and Methods

Twenty sound human third molars were selected in the present study. Teeth were obtained and used in accordance with a protocol approved by the Human Ethical Committee (#660/05, State University of Ponta Grossa, PR, Brasil). The teeth were stored in saline solution at 4°C and used within 6 months after extraction.[8] A flat dentin surface was exposed on each tooth after wet grinding the occlusal enamel on a #180-grit silicon-carbide paper.[9] In the event of pulp exposure, the specimen was discarded. The exposed dentin surfaces were further polished on a wet #600-grit SiC paper for 60 s to standardize the smear layer.[9] After specimen preparation, the indirect restorations were then fabricated directly on the surface of the exposed dentin area. In order to

facilitate the posterior adaptation of the indirect restorations during the luting procedures, a groove was prepared in the mesial or distal aspect of the teeth using of a diamond bur (3031 KG, Sorensen, Barueri, SP, Brazil). This area took part of the restored area and guided the cementation of the indirect restorations.

During restoration fabrication, the teeth were kept moist in saline solution at room temperature. A cylindrical-shaped restoration was constructed using a second generation laboratory processed resin (shade A2, Gradia, GC America, Alsip, IL, USA). The protocol to obtain the indirect restorations followed the application of the resin in four 1-mm-thick consecutive increments. All increments were polymerized for 90 s in a xenon-stroboscopic device (Xenon Pulse Curing System, Kulzer, Belo Horizonte, MG, Brazil). The final composite increment was polymerized for 180 s.

After restoration fabrication, the internal surfaces of the indirect restorations were sandblasted with 50 µm aluminum oxide glass spheres (Sandblaster Micro Etcher, Syosset, NY, USA) for 10 s. The dentin surfaces were then acid-etched (37% phosphoric acid gel) for 15 s, and then water-rinsed for 30 s. Two coats of the adhesive system Adper Single Bond 2 (3M/ESPE, St. Paul, MN, USA) were applied following the manufacturer's directions, and then a blowing air was applied for solvent evaporation (5 s).[10] The dentin surface was kept slightly shiny after adhesive application in all specimens. The light exposure time to polymerize the dentin-bonding agent was 10 s for all groups using a conventional quartz-tungsten-halogen light (Optilux 401 Demetron, Sybron, Newport Beach, CA, USA).

The dual-cure resin cement (3M/ESPE Rely X ARC, St. Paul, MN, USA) was proportioned according to the manufacturer's directions.[11] Thereafter, the resin cement was applied to the internal surface of the indirect restorations and then placed according to their respective guides. Cement excesses were removed and then polymerized for 60 s in all tooth surfaces: buccal, lingual, mesial, distal and occlusal. Different light sources were used in the groups, as described in Table 1.

The power density was assessed using a conventional hand-held radiometer for the QTH light (Demetron Radiometer) and an L.E.D. Demetron Radiometer for the LED lights (Sybron, Newport Beach, CA, USA). All specimens were then stored for 24 h in a dark environment at room temperature (37°C) and 100% relative humidity. After the storage time, the teeth were longitudinally sectioned in both the "x" and "y" directions across the bonded interface with a diamond saw mounted in a Labcut 1010 machine (Extec, Enfield, CT, USA), under water-cooling at 300 rpm. Bonded stick-shaped specimens were obtained with a cross-sectional area of 1.0 (± 0.2 mm²). The stick area was measured with a digital caliper after testing (Digimatic, Mitutoyo, Tokyo, Japan). Individual bonded sticks were positioned in a Universal Testing Machine (DL10000 EMIC, São José dos Pinhais, PR, Brazil) by means of cyanoacrylate-based cement and then subjected to tensile forces at a cross-head speed of 1.0 mm/min until failure. The results were recorded, and the debond stress values, converted into MPa. Data were submitted to one-way ANOVA and Tukey's *post-hoc* test, at a pre-set alpha of 0.05. The distribution of failure mode of the tested specimen was

Table 1 - Description of the experimental groups according to light curing units.

Groups	Light curing unit	Power density (mW/cm²)	Light source classification	Light tip diameter (mm)	Refrigeration system
QTH	Optilux 401 Demetron (Kerr) Lot# 40633009	550	QTH	13	Yes
LED1	L.E.Demetron 1 (Kerr) Lot# 771006811	1,100	Second-generation LED	11	Yes
LED2	Optilight CL (Gnatus) Lot# 501650	620	Second-generation LED	8	No
LED3	Ultralume 5 (Ultradent) Lot# 921552	1,100	Third-generation LED	10 x 13	No

also evaluated at 40 X magnification using a dissecting microscope (Lambda LEB-3, São Paulo, SP, Brasil) and classified as:

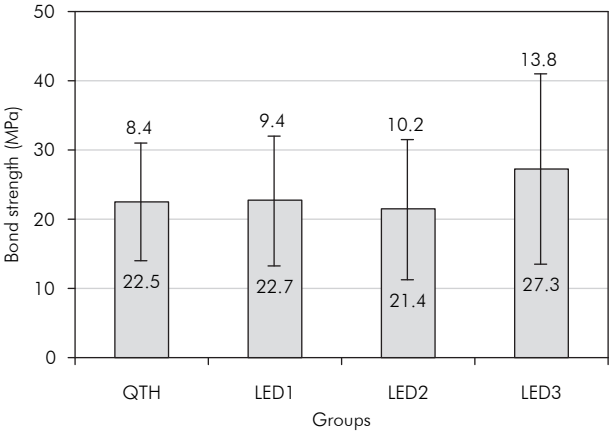
1. Cohesive failure (failure exclusively within the laboratory resin [CR] or dentin [CD]);
2. Adhesive failure (fracture at the composite/dentin interface);
3. Adhesive/Mixed failure (failure at the composite/dentin/resin cement interface including cohesive failures in the neighboring substrates).

Results

The microtensile bond strength values for the experimental groups are shown in Graph 1.

The highest bond strength mean value was seen when the LED3 light (Ultralume 5) was used (27.3 ± 13.8 MPa). The second-generation LED2 light (Optilight CL) presented the lowest bond strength mean value (21.4 ± 10.2 MPa). The control group (QTH light) bond strength mean value was similar to that obtained when the LED1 light was used (22.5 ± 8.4 and 22.7 ± 9.4 MPa, respectively). One-way ANOVA revealed that all the results were statistically equivalent ($p > 0.05$).

The failure modes of the fractured specimens, after microtensile testing, are presented in Table 2. This table also shows the percentage of failure in the experimental groups. The great majority of failures observed were adhesive (from 88% to 100%). The adhesive/mixed mode was the next most frequently observed failure mode (from 0% to 8%). The cohesive failure mode in resin (CR) was observed the least in all the experimental groups (0% to 4%). The cohesive failure mode in dentin (CD) was not detected in any of the microscopic analyses. The overall fracture mode results proved that the predominant failure mode was the adhesive fracture mode (94%).



Graph 1 - Mean and standard deviation of bond strength values according to experimental groups. All values were statistically equivalent ($p > 0.05$).

Discussion

The null hypothesis, that there would be no difference in bond strength when different lights were used to polymerize a dual-cure resin cement in indirect composite restorations, was validated. Statistical analysis revealed no significant difference among the groups ($p > 0.05$). The reason to explain the values when different commercial light curing sources were used to polymerize the resin cement seems to be related neither to their power density output nor to their spectral irradiance. Equivalent bond strength values were observed when the QTH and the LED lights were used to polymerize the resin composite. The second-generation LED2 and the QTH light provided almost the same power density, whereas both the second- (LED1) and third-generation (LED3) LED lights showed an enormous difference in power density, but comparable dentin adhesion values. In addition, in terms of irradiance, the "broad-banded" QTH and LED3 lights provided similar bond strength values compared to the "narrow-banded" LED1 and LED2.

The evolving technology of curing light sources led to the advent of broad-banded LED lights in or-

Table 2 - Percentage of failure modes after microtensile bond strength testing for all experimental groups.

Groups	A %	AM %	CD %	CR %
QTH	88	8	0	4
L.E.Demetron 1 (LED1)	100	0	0	0
Optilight CL (LED2)	100	0	0	0
Ultralume 5 (LED3)	88	8	0	4
Overall percentage of failure mode	94	4	0	2

A: Adhesive failure; AM: Adhesive/Mixed failure; CD: Cohesive failure in dentin; CR: Cohesive failure in resin.

der to allow the photoactivation of all types of resin-based materials, irrespective of the photoinitiator added.[1] An increase in power density in conjunction with a wide spectral distribution seen in the third-generation LED lights produces heating as a consequence.[12,13] Despite the absence of significant differences, the heating produced by the third-generation LED light (LED3) might have led to an additional polymerization, which in turn, can explain why a higher bond strength mean value was observed when this light source was used.

It has been claimed that the resin cement polymerization should be optimized in order to resist deterioration of mechanical and chemical properties, among them strength, hardness, stiffness, and wear resistance.[14] Studies have shown that dual-curing resin cements depend on photoactivation to achieve a high degree of conversion, and thus, a better performance.[15] There is no agreement about the ideal power density needed to obtain optimal energy density, nor is there agreement about the irradiance of the light source, and the exposure time needed to cure resin cements sufficiently.[16] These parameters are of particular interest since, in practice, they are under the control of the clinician.[17,18] On the other hand, the results obtained in the present study do not corroborate these assumptions. In fact, these findings can be explained because a dual resin luting cement was used in the present study. The specimens were evaluated with the microtensile bond strength test after 24 h, time after which the resin cement may have chemically completed its polymerization.[19] Irrespective of the light source used, the results proved that the bond strength was significantly equivalent.

Dual-curing resin cements have been used for luting indirect esthetic restorations and most recently metal castings such as crowns and fixed partial dentures, as an alternative to zinc phosphate and glass ionomer cements.[20] Some advantages of this type of resin cement are low solubility, adequate consistency and film thickness, superior mechanical properties, optimal bonding to dental structures and restoring materials by adhesive systems and reduced microleakage.[21,22] Since the introduction of LED sources by Millis in 1995, several concerns about their efficiency for the light curing of resin-based materials have arisen. Regarding resin composites, several studies have demonstrated that LED devices are effective.[23,24] On the other hand, as regards resin cements, few studies[25-27] have only reported no significant differences using shear bond strength testing when QTH devices were compared to high-intensity LED light sources to polymerize a dual-cure resin cement through a 3-mm-thick ceramic restoration. It has been claimed that LED light units with a relatively low power output require a higher exposure time to perform as well as QTH lights.[12]

The findings observed in the present investigation suggest that, although high-intensity LED lights were also used to activate the resin cement, the polymerization of this restorative material was effective. The bond strength values seen in the experimental groups were equivalent. Clinically, the use of a light source when cementing an indirect restoration is important to allow immediate polymerization of the marginal cement, avoiding premature crown removal. Polymerization completion in the areas not reached by the curing light energy occurs through chemical reaction, which takes about 24 h,[11] and it is essential for achieving adequate bond strength to the dental tissues. Also, despite the evolving technology, the conventional broad-banded QTH lights are effective for light curing of resin-based materials and can still be considered a control light for being able to polymerize all resin-based materials, irrespective of the photoinitiator.

Conclusion

Based on the results observed in the present study it can be concluded that the different light curing sources tested for light activation of the dual-cure resin cement did not influence the bond strength of a laboratory-processed composite to dentin tissue. Neither the power density, nor the spectral irradiance seems to interfere on the bond strength of the resin cement.

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